Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	}	
	}	
Amendment of the Commission's Rules with Regards to Commercial Operations in the 3550-3650 MHz Band	} } }	GN Docket No. 12-354

To: The Commission

Comments of CTVR

CTVR is a national telecommunications research centre based in Ireland. We have experience in the area of industry-informed research, development and prototyping of software radio systems, cognitive systems, DSA systems and TVWS systems[1]. We welcome the Commission's proposals to create a new Citizens Broadband Service in the 3550-3650 MHz band using techniques which will exploit both Small Cells and Spectrum Sharing. More specifically in this Comment we suggest a mechanism for use by the SAS which can address concerns relating to Access Coordination and Interference Mitigation firstly among Priority Access Users, secondly between GAA users and Priority Access users and finally among GAA users themselves. Simply put, we suggest that the SAS should employ a dynamic *Least Restrictive Mask* assignment mechanism which adapts the In-band and Out-of-Band power restrictions on the licensed Priority Access and GAA users in accordance with the observed local scenarios which are registered with the SAS. The suggested modalities of such a mechanism, which is built around an adaptation of the regulatory tool known as the Block Edge Mask (BEM), are

[1] CTVR is a member of the European COGEU consortium which addresses business, regulatory and technical issues surrounding TVWS exploitation by cognitive devices (http://www.ict-cogeu.eu).

briefly outlined in this Comment. The use of dynamically assigned least restrictive masks will also help to maximise spectral efficiency for Small Cells on a scenario-by-scenario basis.

1. A Least Restrictive Mask assignment mechanism for the SAS

This proposal is based on three building blocks, none of which is radical; a pixelated geo-location registration system for both Priority Access and GAA Small Cell systems; a scenario-specific modelling of interferer-to-victim protections using pixel-based system locations; an assignment of the minimally restrictive Small Cell Edge Mask (SCEM) to each Small Cell system.

a. Pixelated geo-location database

Our Comment builds on the concept of the GAA Zones and Priority Access Zones suggested in the NPRM. The geographical area of these zones would be divided into a 2D grid of pixels, with a third dimension of frequency. For example, in Figure 1, the starred pixel is registered as being occupied by a Priority Access Small Cell system. Consequently, the surrounding pixels have been marked occupied at that frequency.

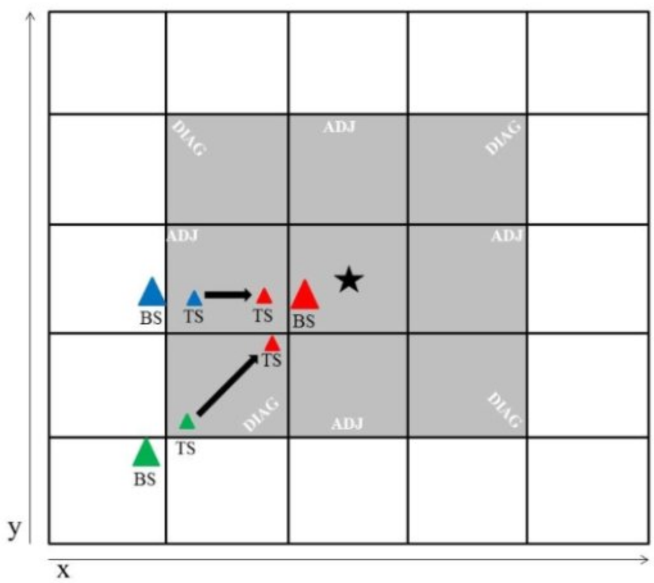

Figure1: Pixelated database

The sizes of the pixels are chosen such that, even when the base stations are as close as they could possibly be within the non-blocked pixels, there is still enough path loss to bring the co-channel interference below the noise floor. Such a pixelated approach allows for a highly tractable and efficient means of calculating the interferer-victim relationships from one pixel to an adjacent one as there will be a finite number of interactions to consider. We suggest pixilation is well suited for a database managing Small Cell systems at 3.5 Ghz as the fidelity of a pixelated approach when compared to one using exact locations is high. This would not be the case for higher powered systems at lower frequencies such as for the TVWS database.

b. Pixel-based Interference Modelling

The interference mitigation approach we propose is based on the use power limits for the interferer. A SCEM is functionally similar to the BEM in that it consists of an In-Block (IB) power limit as well as two Out-Of-Block (OOB) limits, one on each side. These limits address interference issues in a service and technology neutral manner at the interfaces identified in Figure 2.

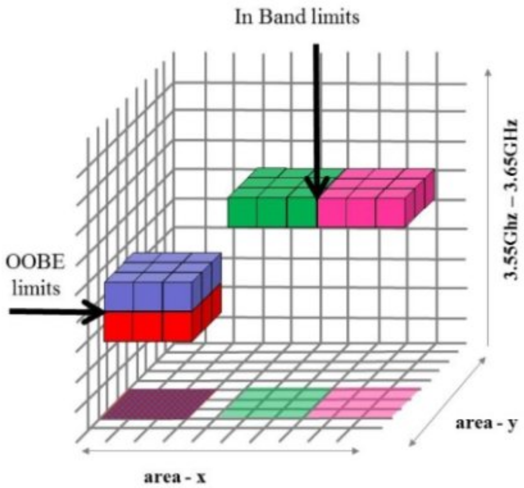

Figure 2: OOB limits protect from interference between geographically co-located systems on adjacent frequencies, in-band limits protect from interference between geographically adjacent systems on the same frequency.

The difference is that a SCEM defines an emission profile for a single Small Cell system as opposed to an entire frequency block. The SCEM will also be dynamically defined based on the current scenario, i.e. taking into account the other neighbouring independent and unaffiliated systems, such that the least restrictive mask is assigned. This approach has the effect of maximising the spectral efficiency for each scenario. These masks are determined by assessing the impact of interferers on victims systems using a statistical modelling technique[2]. Each Small Cell system will be assigned two masks; one for its base station (BS) and one for its terminal stations (TS). Owing to the use of a pixelated geo-location database there will be a large, but finite, number of possible interactions between various combinations of PA and GAA Small Cell systems.

Table 1 Interference management scenarios[3]

Scenario	Number of Interfering Systems	Frequency and spatial relationship to victim : Restriction required (OOB, IB)	Interferer pixel adjacency to victim is diagonal or beside	
1	1 GAA	FA & GC: OOB level		TS -> TS
2				BS -> TS
3				TS -> BS
4		FA & GA: OOB level	beside	TS -> TS
5				BS -> TS
6				TS -> BS
7			diagonal	TS -> TS
8				BS -> TS
9				TS -> BS
10		FC & GA : IB level	beside	TS -> TS
11				BS -> TS
12				TS -> BS
13			diagonal	TS -> TS
14				BS -> TS
15				TS -> BS
16	2 GAA	FA & both GC: OOB level		TS -> TS
17				BS -> TS
18				TS -> BS
19		FA & 1 GA, 1 GC: OOB level	1 beside	TS -> TS
20				BS -> TS
21				TS -> BS
22			1 diagonal	TS -> TS
23				BS -> TS
24				TS -> BS
25		FA & 2 GA: OOB level	1 beside, 1 diagonal	TS -> TS
26				BS -> TS
27				TS -> BS
28			2 diagonal	TS -> TS
29				BS -> TS
30				TS -> BS
31			2 beside	TS -> TS
32				BS -> TS
33				TS -> BS

[2] ECC report 131, DERIVATION OF A BLOCK EDGE MASK (BEM) FOR TERMINAL STATIONS IN THE 2.6 GHz FREQUENCY BAND (2500-2690 MHz)
[3] FA= Frequency Adjacent, GC = Geographically Collocated, FC = Frequency Collocated, GA = Geographically Adjacent.

For each scenario, the In-Block mask limits for a Small Cell system take into account the size of the Cell Radius and Cell TS Density, i.e. the number of TS devices that are attached to the licensed Small Cell system, as well its proximity to other systems on the same frequency. The OOB limits for a Small Cell in a given scenario are also determined by its Cell Radius and Cell TS Density and by the Cell Radius and Cell TS Density of the potential victim systems on adjacent frequencies. Where there are multiple Small Cell GAA systems occupying the same pixel, they will each receive the same masks. In order to account for multiple possible scenarios of interferer-victim interactions, the SAS Least Restrictive Mask mechanism would employ a database of *pre-calculated* masks for every possible combination of factors. As these parameters fluctuate, i.e. the number of TS devices can rise and fall, so does the appropriate least restrictive SCEM.

Table 1 illustrates some of the combinations of interference system/victim system geometries for which masks are pre-calculated and stored in the database. The victim system in Table 1 is presumed to be a Priority Access system. Each line in Table 1 corresponds to an interference scenario. Each scenario can vary by; whether the interferer and victim are frequency adjacent or frequency co-located; whether the interferer and victim are geographically adjacent (beside/diagonal) or geographically co-located (see figure 4); whether there is one interfering system or two (possibly more); whether the interference is between two terminal stations or a base station and a terminal station.

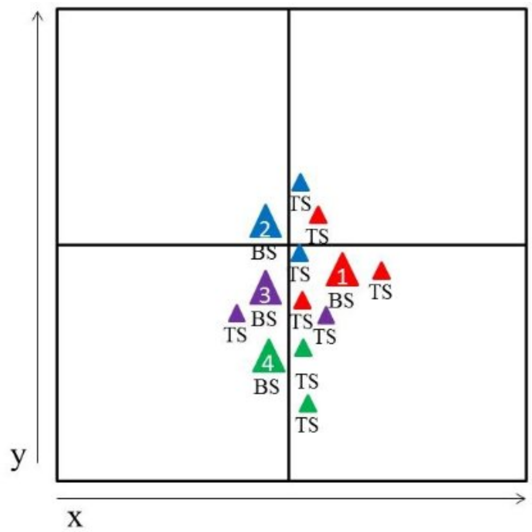

Figure 4: A number of geographically collocated and adjacent systems on adjacent frequencies

Figure 4 illustrates some of the different possible permutations of interference interactions between frequency adjacent systems. BS1 and BS2 are diagonal to each other; this configuration will (statistically) cause the least interference. BS3 and BS4 are in the same pixel which is the configuration likely to cause the most interference. If we assume that BS2 is a PA system, then we would need to assign a mask from the database which accounted for 3 frequency-adjacent GAA systems, where 2 GAA systems (BS3 and BS4) were geographically-adjacent (beside) it and the third GAA system (BS1) was geographically-adjacent (diagonal).

As suggested by the NPRM, we agree that the GAA users should be purely opportunistic users of the 3.5 Ghz band. We suggest that multiple GAA users should be allowed to operate simultaneously at the same frequency; the 3.5 Ghz band may be segmented or channelized, an approach which would also work with our suggested mechanism. A GAA user, if registered as being alone at a pixel would be assigned a SCEM which would allow it, alone, to maximise the spectral efficiency of that opportunity. However, if a second GAA user registered to use the same pixel (or an adjacent pixel) the power of both would have to drop such that; their aggregate IB & OOB interference does not cause other systems interference, and they will not cause each other too much co-channel interference. The degree to which co-channel interference can be tolerated among GAA users will be dependent on what TS receiver and cell radius characteristics the Commission deems appropriate for Small Cell systems.

c. Deriving Appropriate Small Cell Edge Masks

The calculations to derive the SCEMs are adapted from the ECC report on block edge mask derivation[4]. In order to construct a SCEM, three limits are needed; the IB EIRP and the OOB EIRP for each side of the mask. The IB power limit in this case can be determined by the desired cell size and minimum SNR of the Small Cell system in question. If there is a minimum SNR and a desired cell radius size then the IB power limit can be determined simply by examining an appropriate path loss model. We note that the Commission has requested comment on the appropriate propagation models to be used for Small Cells at 3.5 GHz.

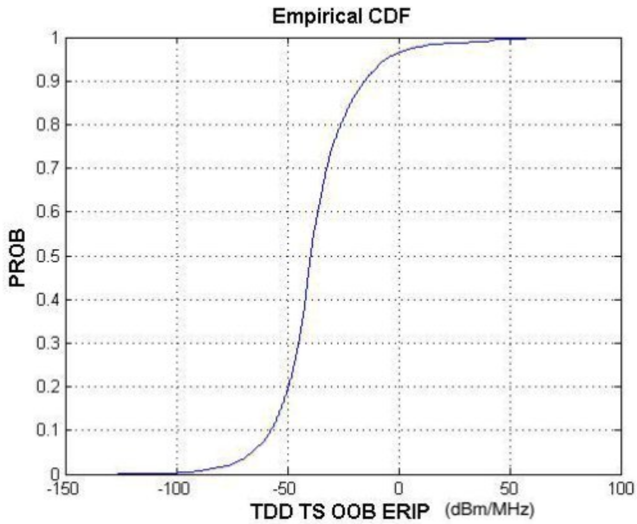

Figure 3: CDF of OOB levels

If the minimum SNR is known and if there is an estimation of the noise floor then the IB power corresponding to the desired cell radius size can be determined. This level can be adjusted as aggregate interference is taken into account. The OOB EIRP is the acceptable interference in a band as a result of interference from the adjacent band. This is calculated by performing a statistical Monte-Carlo analysis on two neighbouring systems that are geographically co-located and frequency adjacent.

[4] Karimi, H.R.; Lapierre, G.; , "Derivation of block-edge masks for TDD and FDD terminal stations in the 2500–2690 MHz band," *Global Mobile Congress 2009* , vol., no., pp.1-6, 12-14 Oct. 2009
doi: 10.1109/GMC.2009.5295851

From this analysis a cumulative distribution function (CDF) is produced (Figure 3). Depending on how reliable the mask needs to be, an OOB anywhere from 95-98% of the realizations can be accepted. This value is the OOB level for the mask at the edge between these two systems. This process would be repeated for the other edge giving both sides. It is important to note that this process would be repeated for *all reasonable (or expected) values for density (d)* so that the database can assign new mask values as the TS densities of the cells vary.

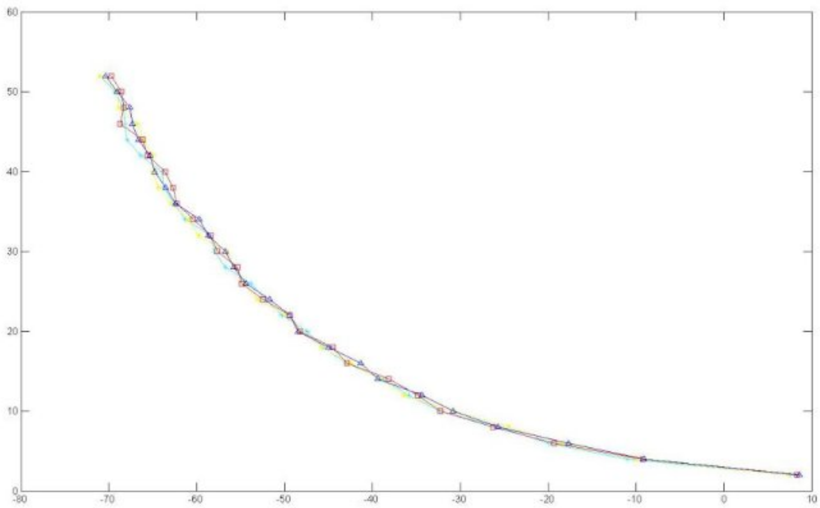

Figure 4: OOB levels varying with TS denisty of interfering system

The graph in Figure 4 represents the OOB level plotted against the TS densities of the two frequency adjacent, geographically co-located Small Cell systems. This sample graph shows the OOB limits for a GAA user adjacent to a PA user where the PA user has a TS density of 20 in its system and the GAA user's TS density is varied from 2 to 52. This graph corresponds to Scenario 1 in Table 1. If the GAA user reports when its TS density passes certain thresholds the database would use this data to assign a new OOB limit. If another GAA user were to come online at the same frequency and geographic location then the interference scenario would change to Scenario 16; and both GAA users would then be assigned OOB limits based on the data for that scenario. In Figure 5 we can see the dataset for two GAA users that are frequency and geographically co-located.

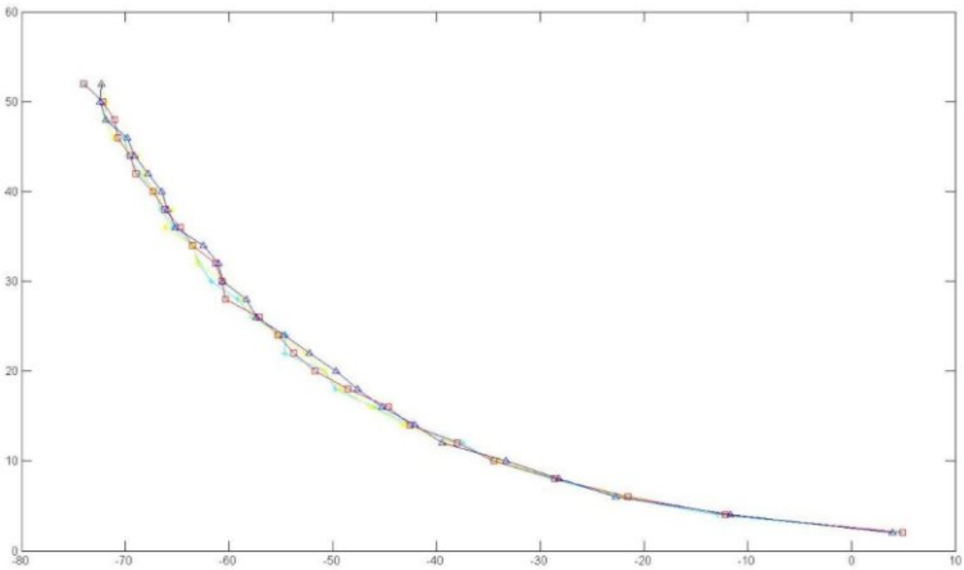

Figure 4: OOB levels varying with TS denisty of two interfering systems

The key difference in these two interference scenarios is that it is possible for twice as many terminal stations to be transmitting at the same time when the aggregate interference is taken into account; the division of the interference allowance between different terminal stations results in a stricter mask. These two interference scenarios serve only as an example and if this kind of system were to be implemented, similar calculations would have to be performed for every interference scenario and every possible combination of TS densities. The combinations can also be extended to include mixes of TDD and FDD based systems.

2. Summary

CTVR welcomes the Commission's proposals to advance Spectrum Sharing and Small Cell technology by adopting a dynamic Spectrum Access System in the 3.5GHz band. We strongly suggest that this band is well-suited to a more nuanced and sophisticated database-driven management approach than has been employed heretofore in the TVWS. As such we suggest the that Commission should investigate further the use of interference masks for Small Cell systems on the basis of a Least Restrictive Mask assignment mechanism in the SAS. We believe that a highly tractable database-driven solution is possible for Small Cells operating at 3.5 GHz if the geographic Zones are subject to appropriate pixilation. The dynamic assignment of scenario-based Small Cell Edge Masks will have the effect of both mitigating interference risks between and among the Priority Access and GAA systems as well as maximising the spectral efficiency of these systems on a scenario-by-scenario basis.

Respectfully submitted,

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